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Vasquez et al.

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(54) **SYSTEM AND METHOD FOR MONITORING AN ELECTRICAL DEVICE**

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Related U.S. Application Data

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(51) **Int. Cl.**

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H02H 1/00	(2006.01)
H02H 3/00	(2006.01)
H02H 3/08	(2006.01)
H02H 5/04	(2006.01)
H01H 83/20	(2006.01)

(52) **U.S. Cl.**

CPC ***H02H 1/0092*** (2013.01); ***H02H 3/00*** (2013.01); ***H02H 3/08*** (2013.01); ***H02H 5/04*** (2013.01); *H01H 83/20* (2013.01); *Y10T 307/469* (2015.04)

(58) **Field of Classification Search**

USPC 307/113, 116; 361/42

See application file for complete search history.

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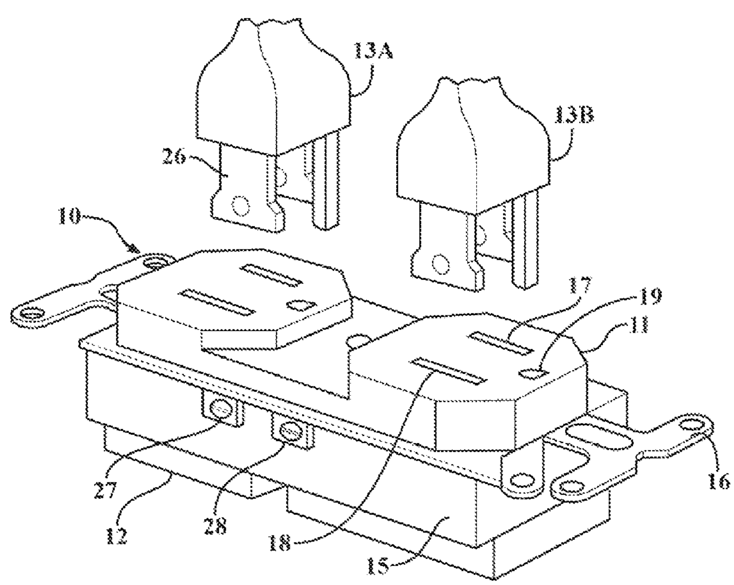
(74) *Attorney, Agent, or Firm* — Mitchell M Musial, PLLC

(57) **ABSTRACT**

Disclosed herein is a device for monitoring the condition of a branch circuit. A device contains a switch that is normally open to prevent the occurrence of electric shock. An optical prong detector is provided to determine weather both the hot and neutral prongs of a plug have been inserted into the receptacle. The receptacle provides conductance upon determination of insertion of a plug into the receptacle. Additional features include GFI detection, current detection heat detection warning lights and an audible alarm. The receptacle includes communication abilities with remote devices to transmit data indicative of the state of the device.

19 Claims, 16 Drawing Sheets



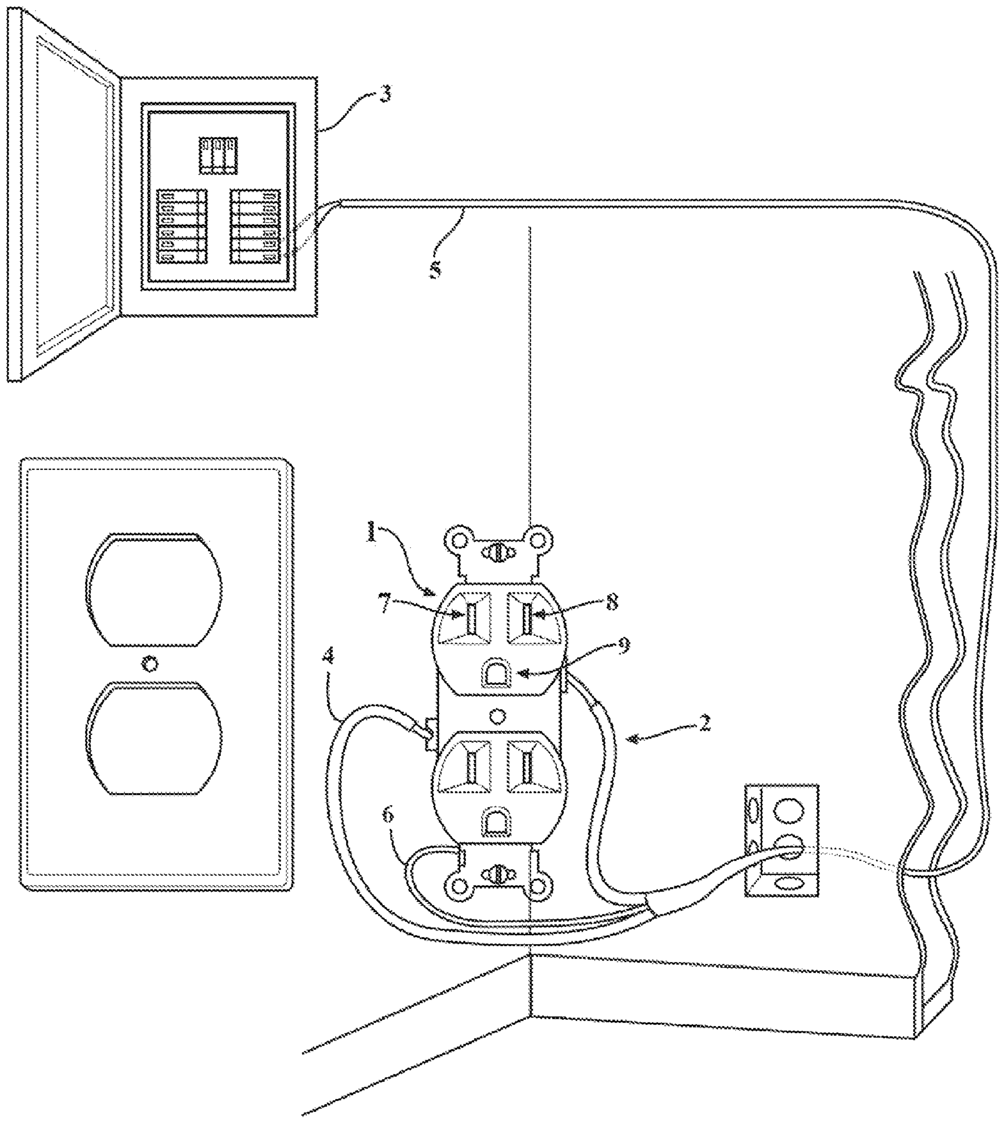
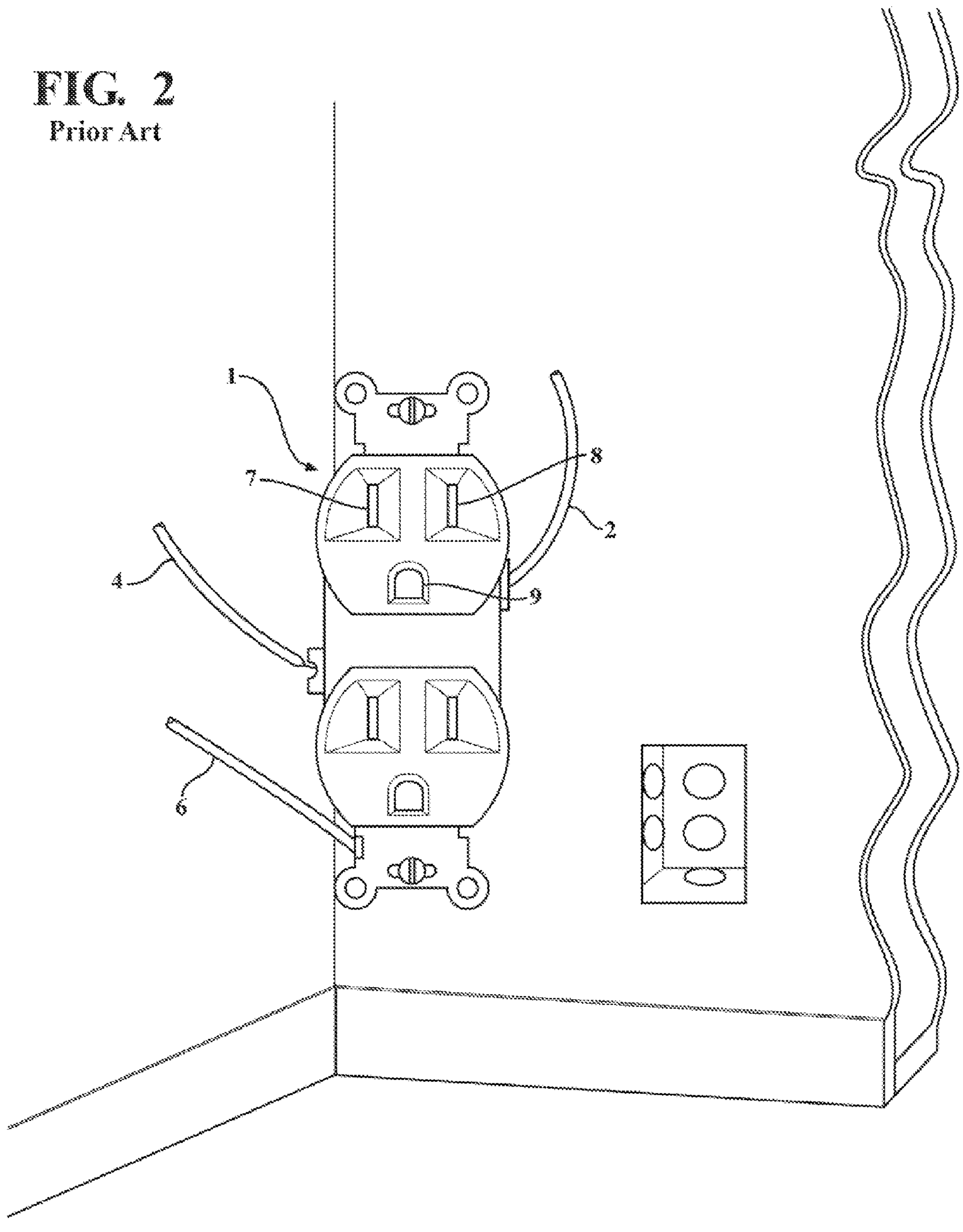


FIG. 1
Prior Art

FIG. 2
Prior Art



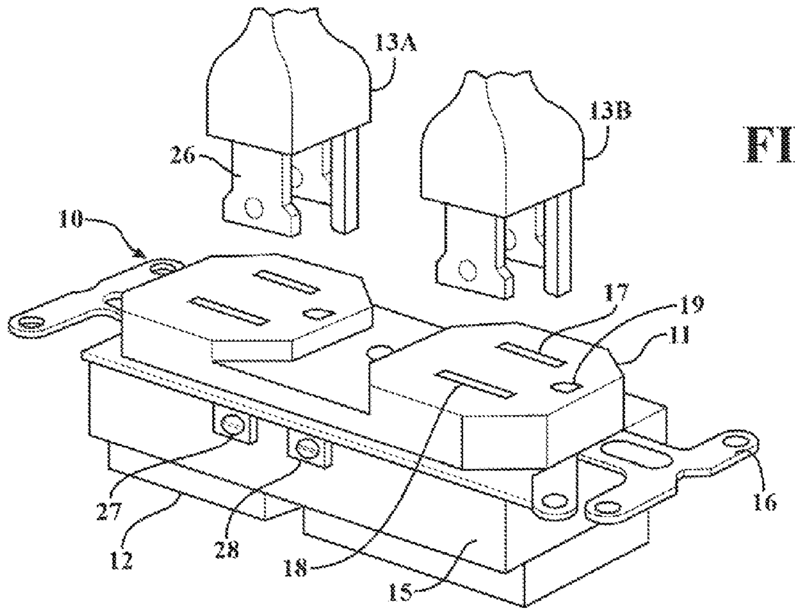


FIG. 3A

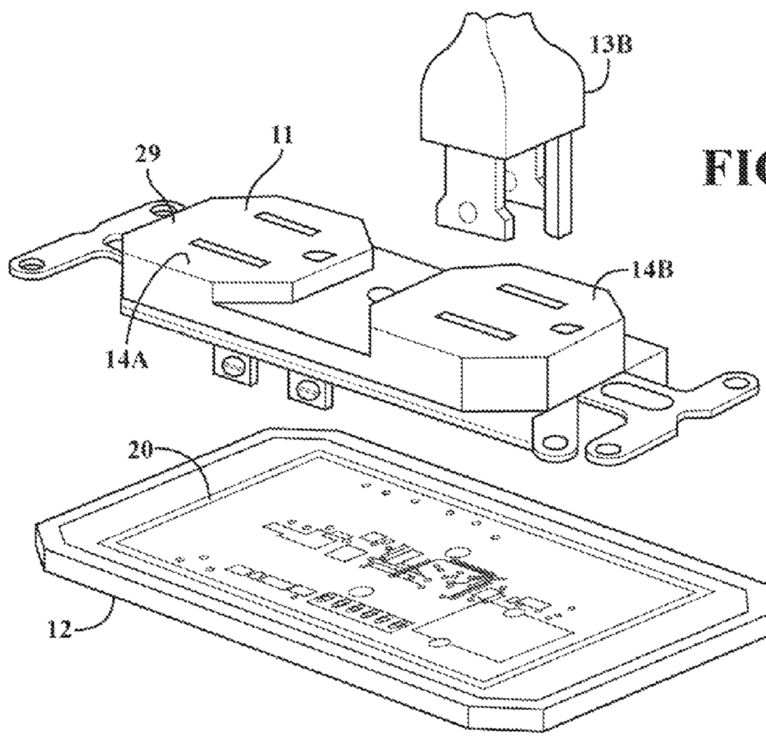


FIG. 3B

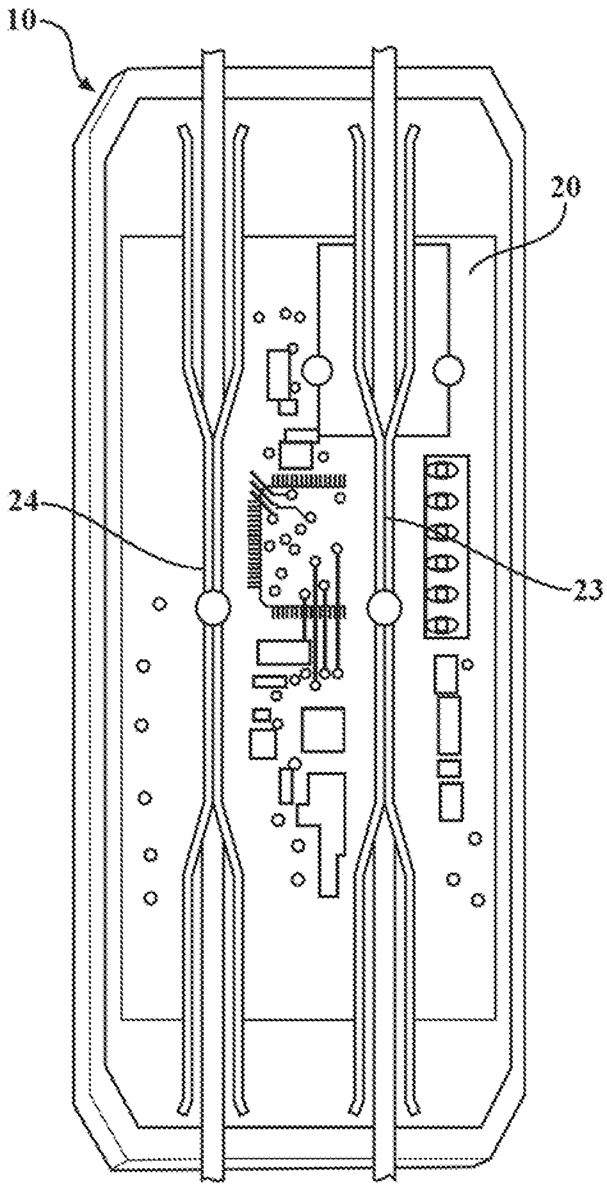


FIG. 4

FIG. 5

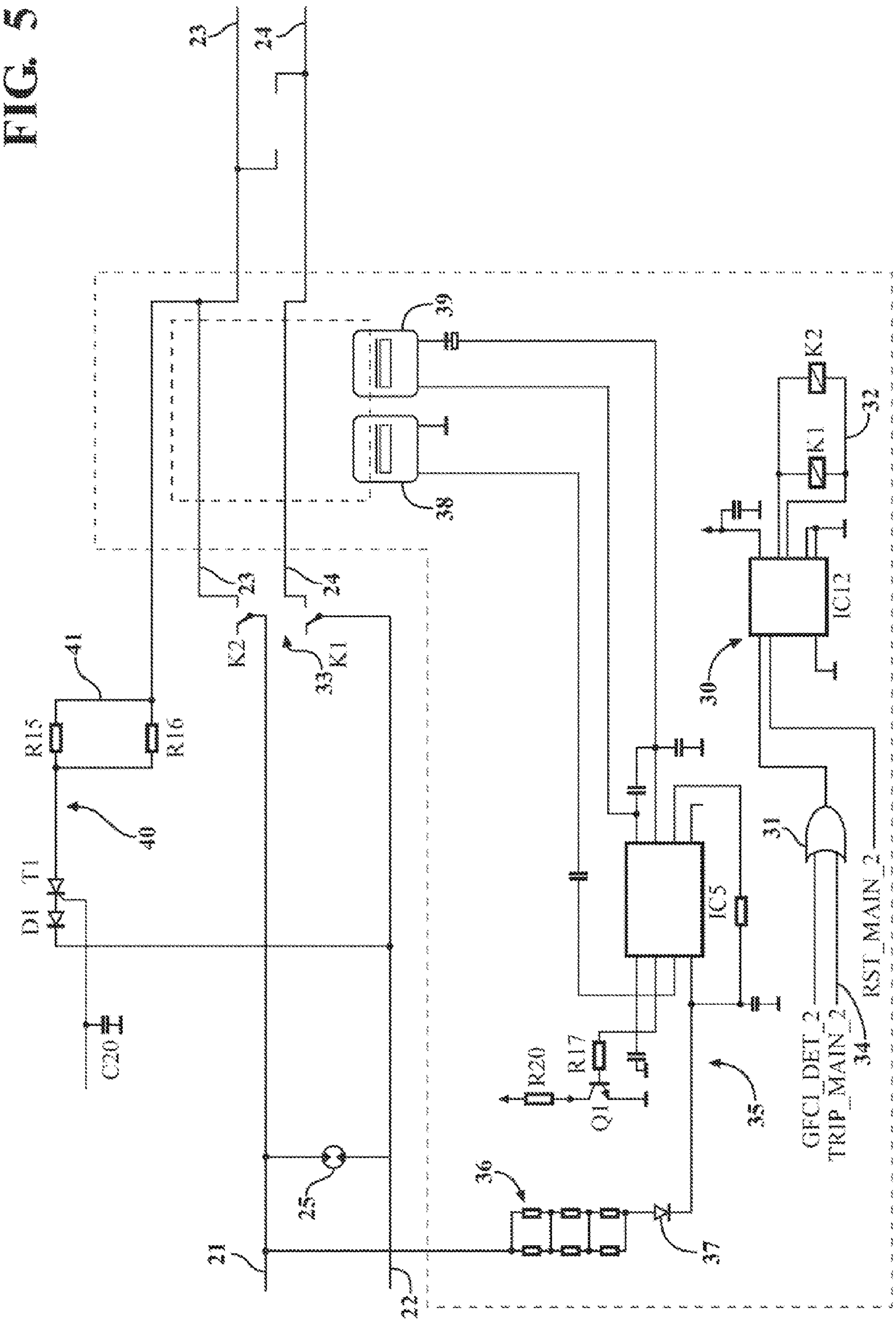

23
24
39
38
K2
K1
32
IC12
30
41
R15
R16
23
24
K2
33
K1
40
D1
T1
C20
IC5
31
GFCI_DET_2
TRIP_MAIN_2
RST_MAIN_2
34
35
R20
R17
Q1
36
25
21
22
37

FIG. 6

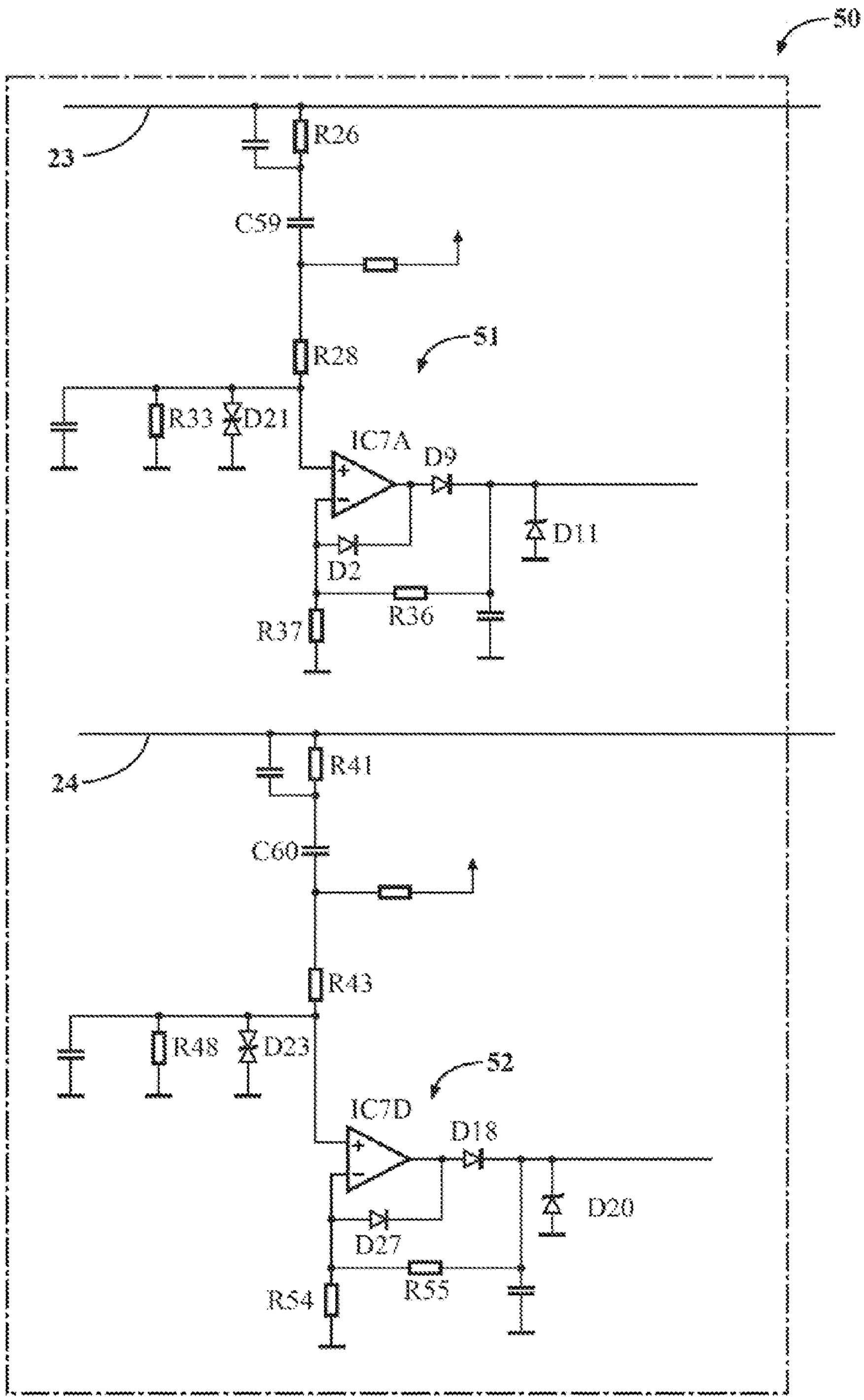
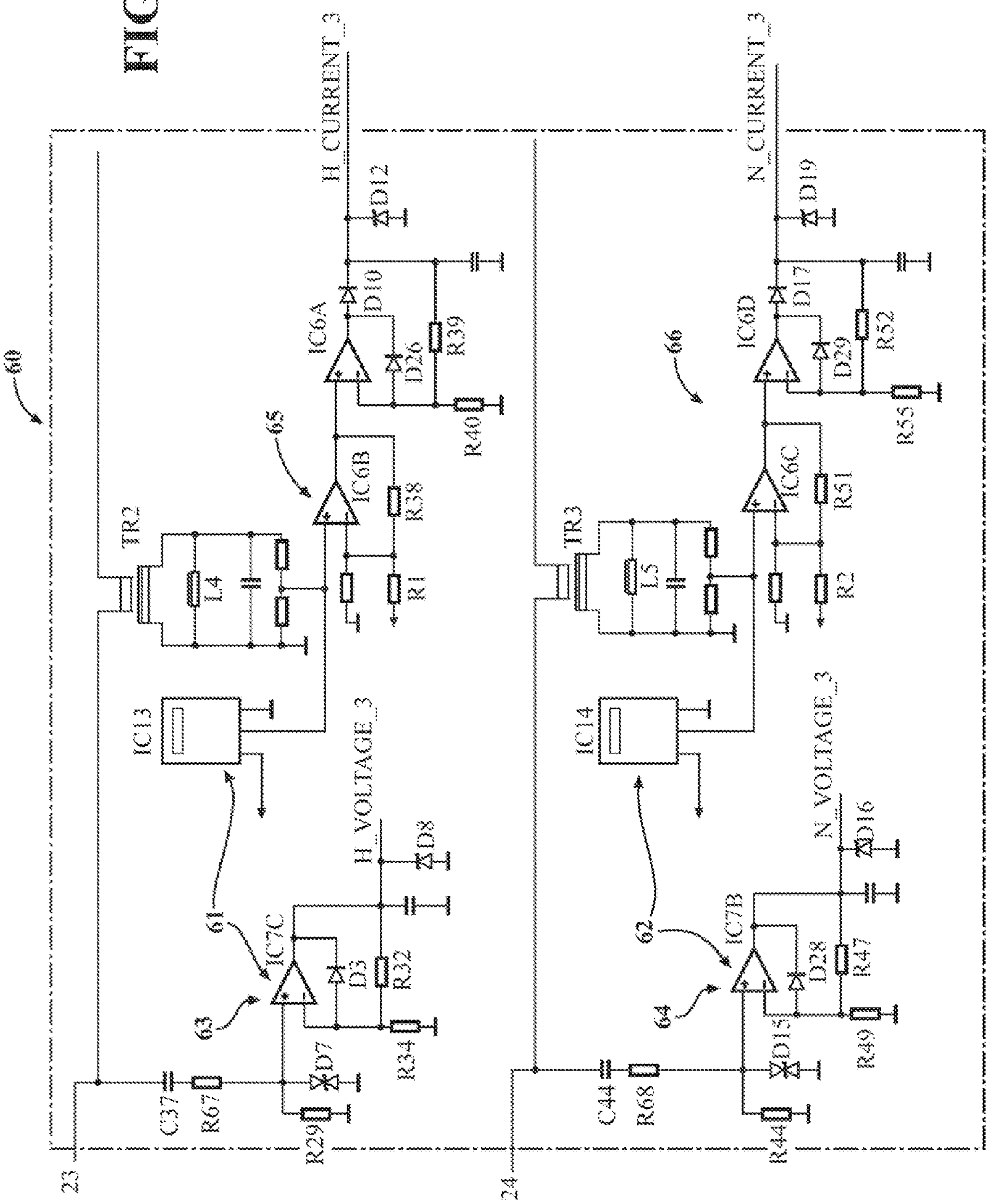

50
23
R26
C59
R28
51
R33
D21
IC7A
D9
D11
D2
R37
R36
24
R41
C60
R43
R48
D23
52
IC7D
D18
D20
D27
R54
R55

FIG. 7


60
H_CURRENT_3
D12
D10
IC6A
D26
R39
R40
65
IC6B
R38
TR2
L4
R1
IC13
H_VOLTAGE_3
D8
61
IC7C
D3
R32
63
R34
D7
C37
R67
R29
23
N_CURRENT_3
D19
D17
IC6D
66
D29
R52
R55
IC6C
R51
TR3
L5
R2
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D15
R49
C44
R68
R44
24

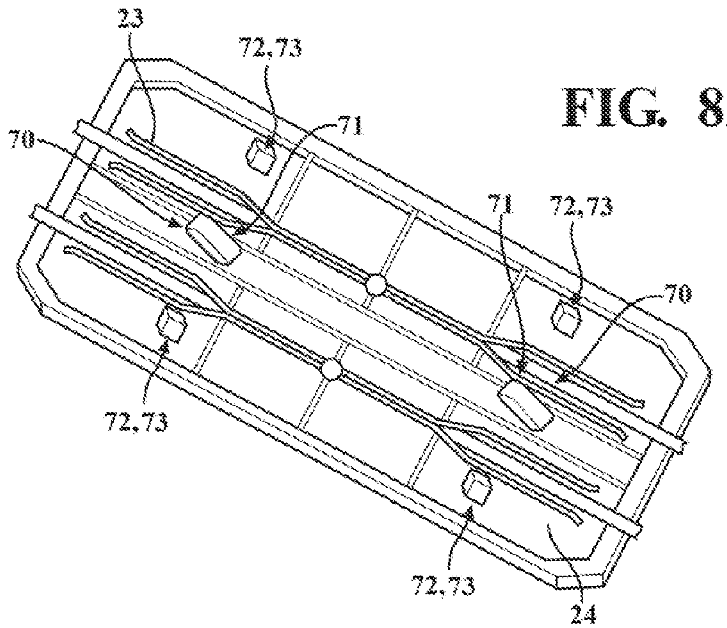


FIG. 8A

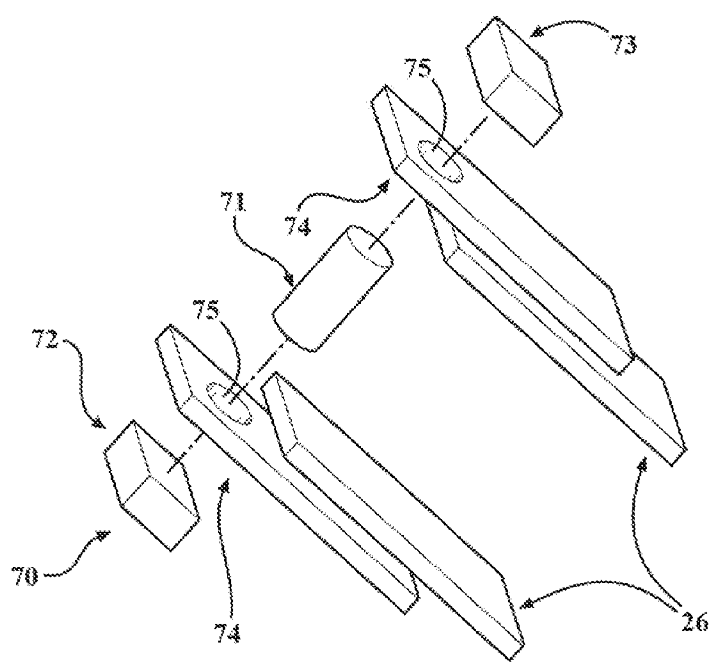


FIG. 8B

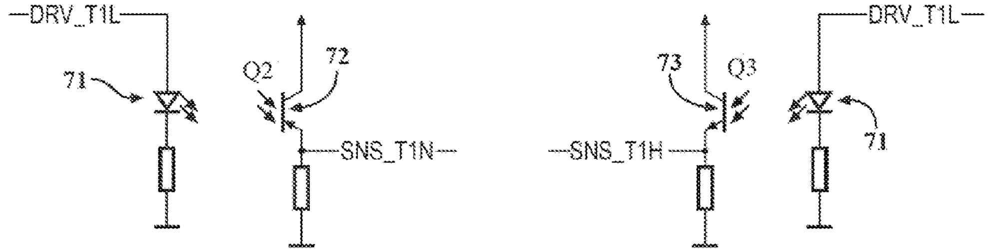

DRV_T1L
71
Q2
72
SNS_T1N
73
Q3
DRV_T1L
SNS_T1H
71

FIG. 8C

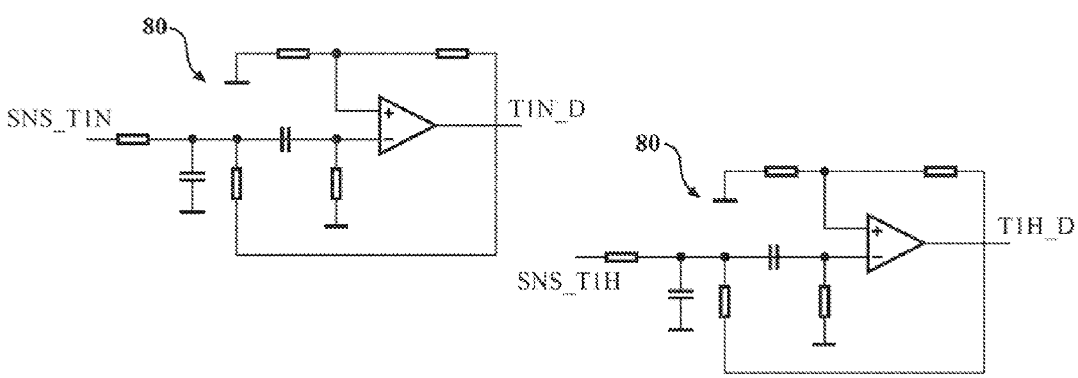

80
SNS_T1N
T1N_D
80
T1H_D
SNS_T1H

FIG. 8D

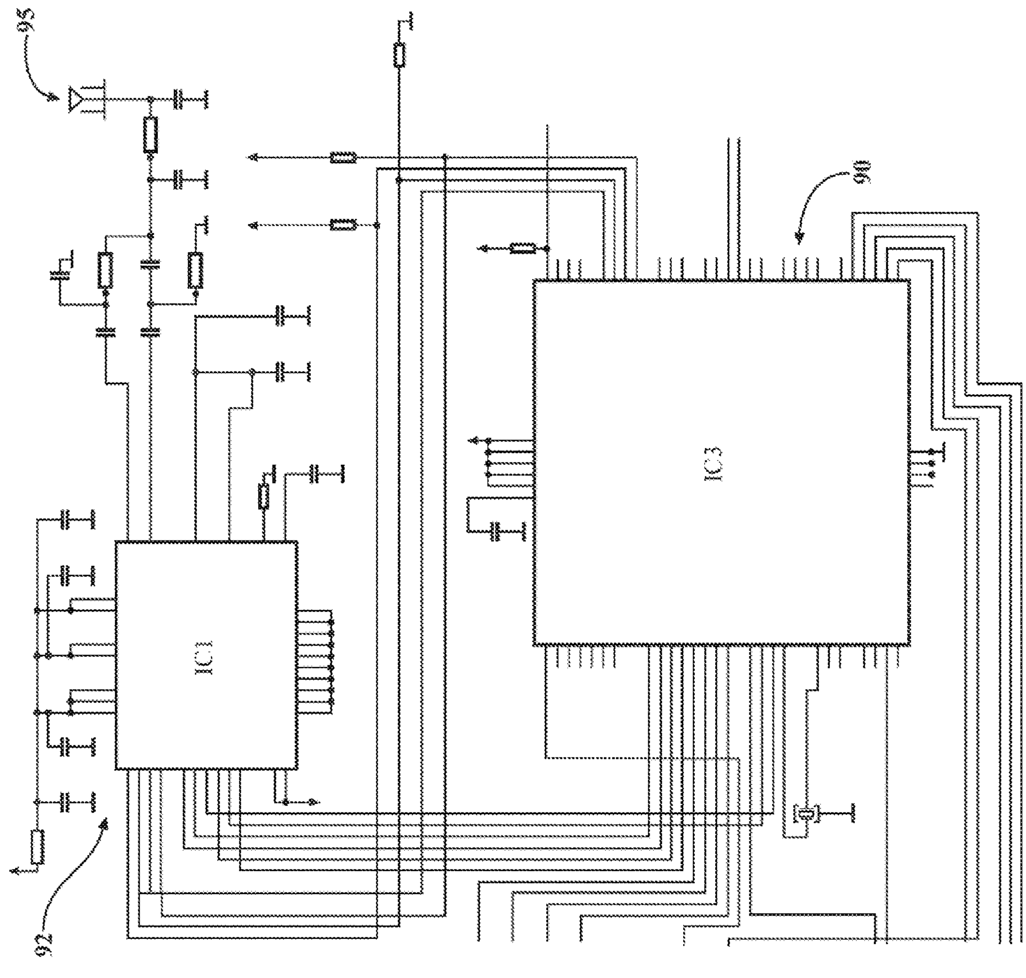
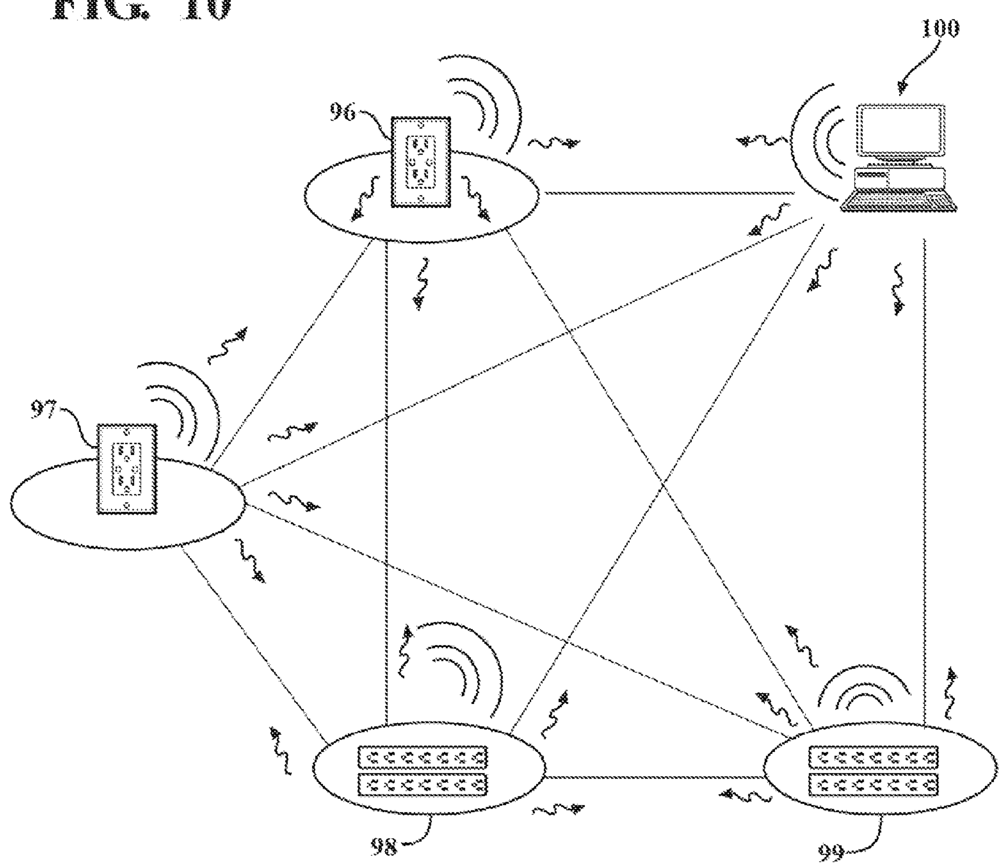
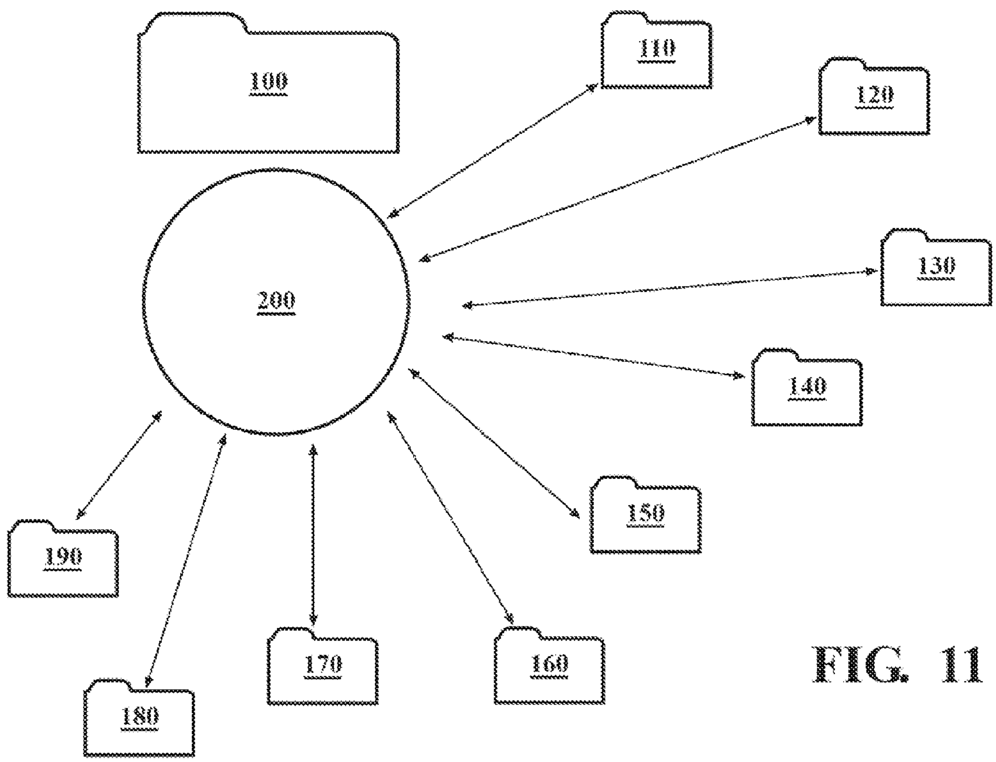


FIG. 9

FIG. 10




100
110
120
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140
150
160
170
180
190
200

FIG. 11

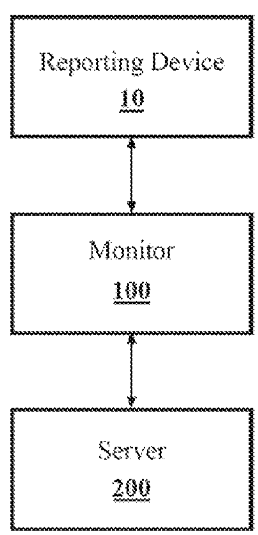

Reporting Device
10
Monitor
100
Server
200

FIG. 12

FIG. 13

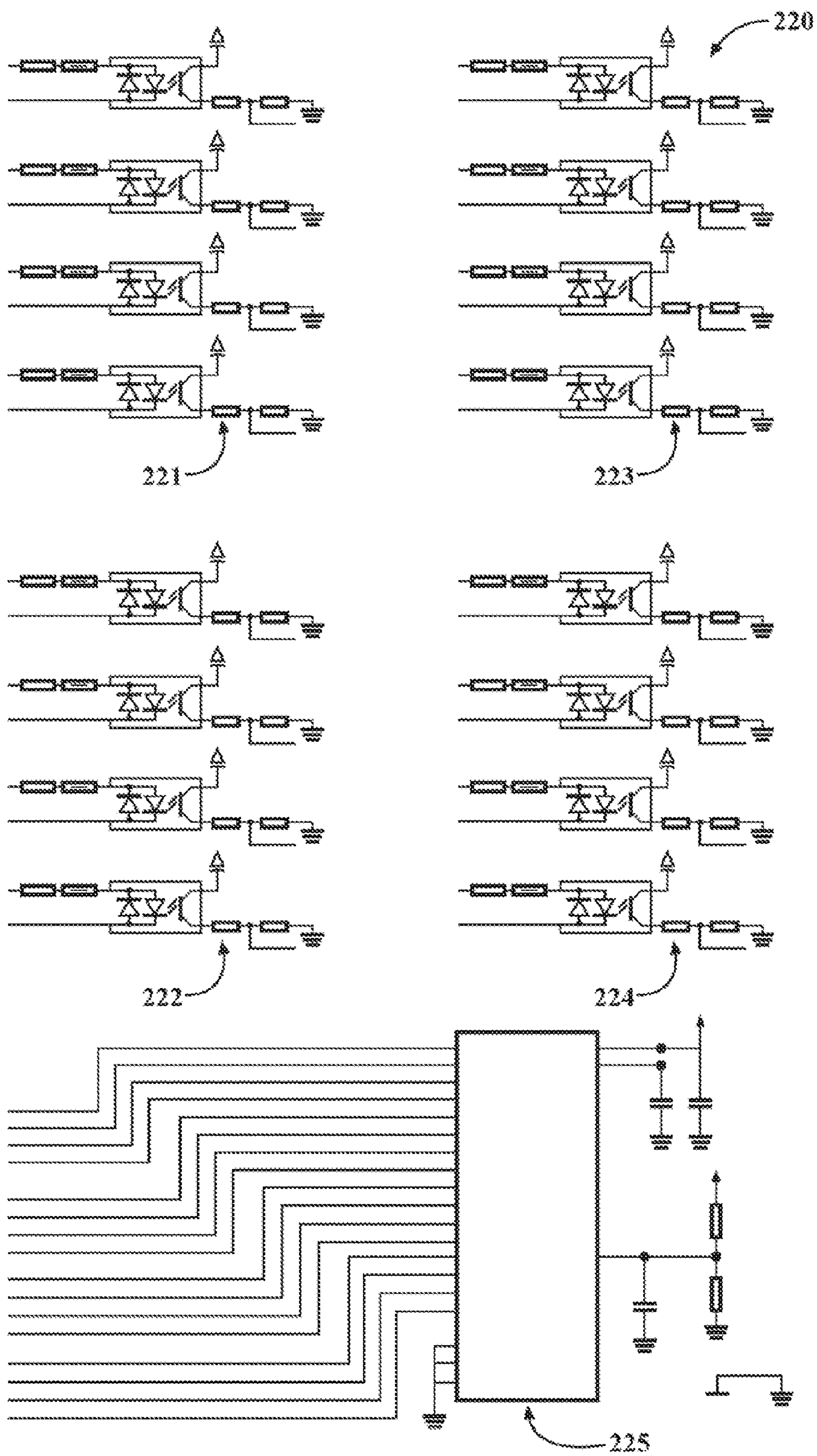


FIG. 14A

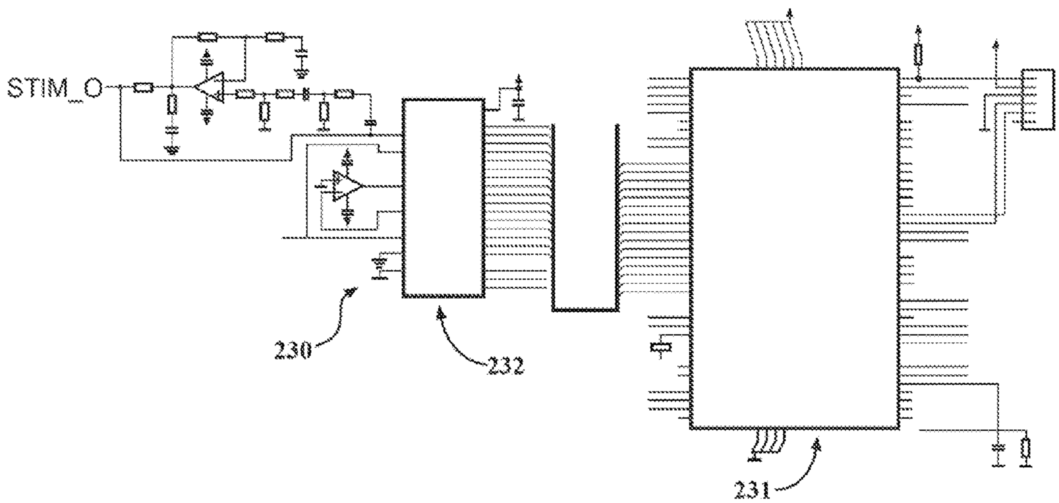


FIG. 14B

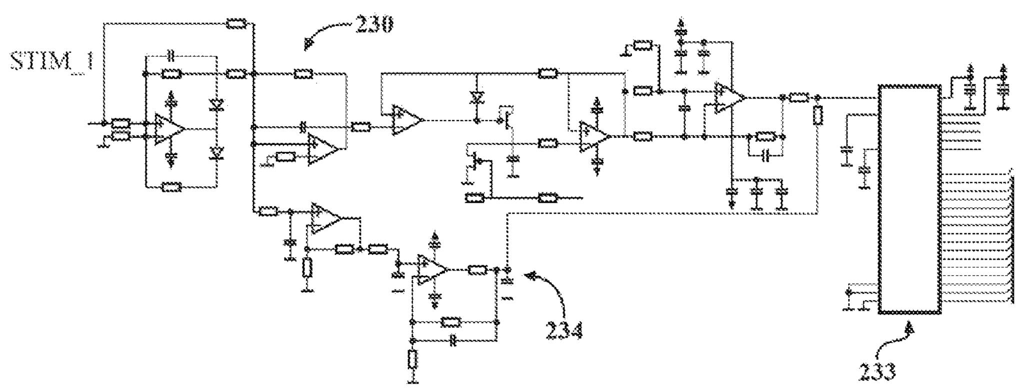
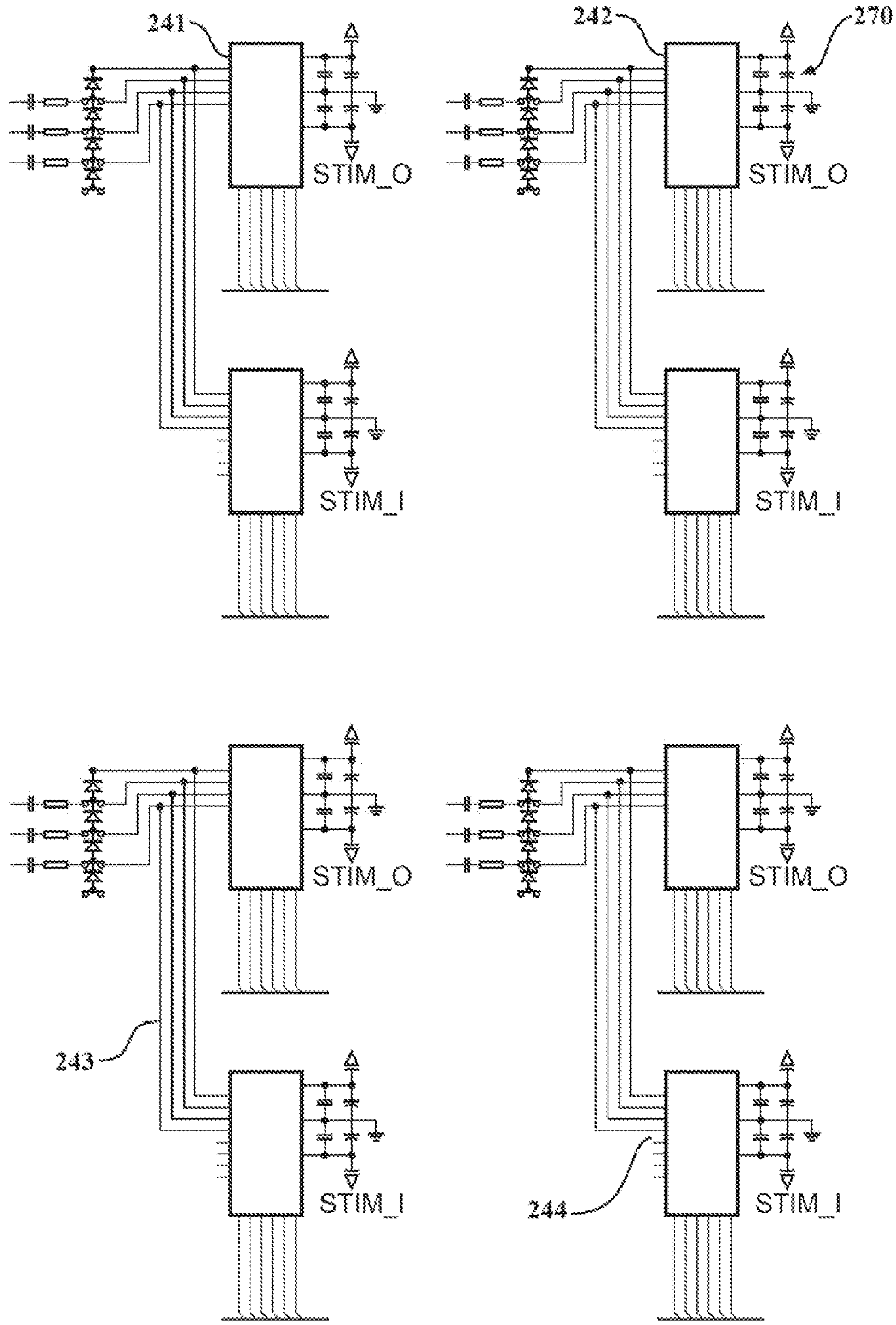


FIG. 15



241
242
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STIM_O
STIM_O
STIM_I
STIM_I
STIM_O
STIM_O
243
STIM_I
244
STIM_I

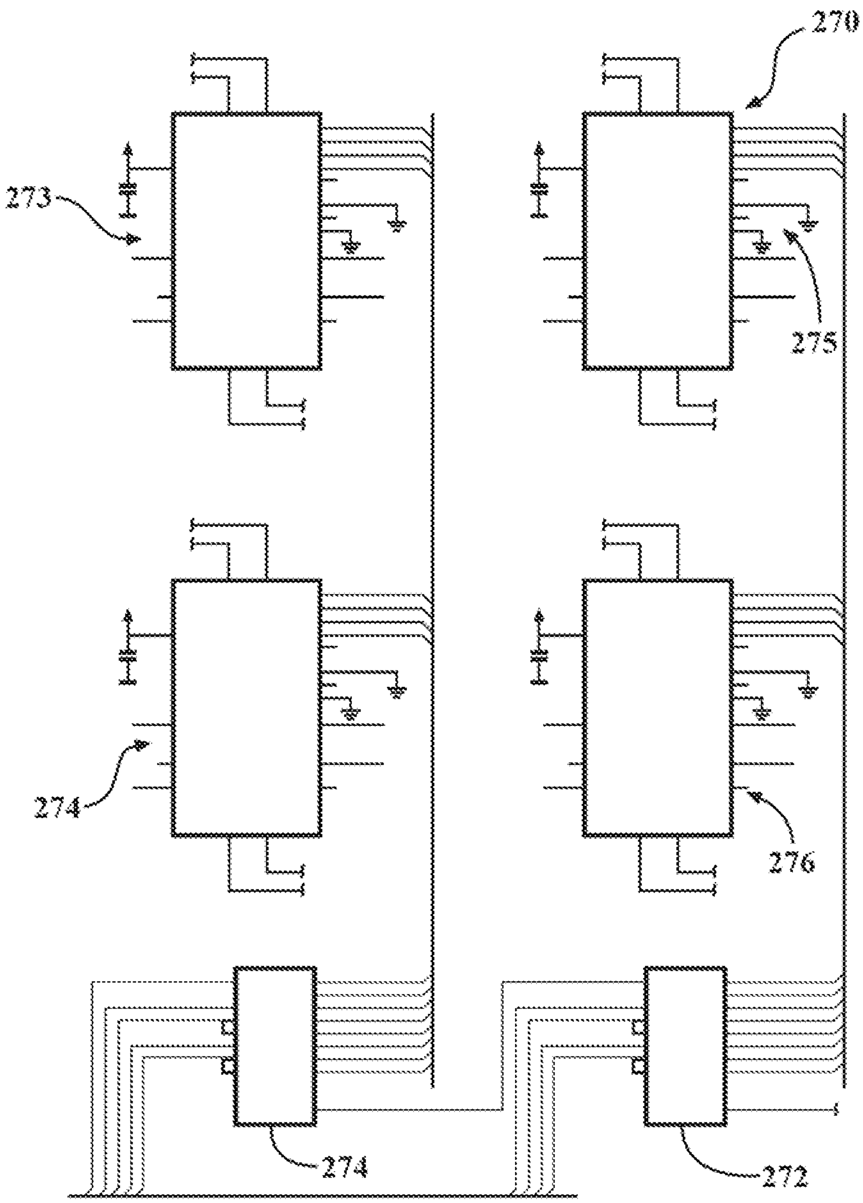

FIG. 16

SYSTEM AND METHOD FOR MONITORING AN ELECTRICAL DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. application Ser. No. 12/493,522, entitled "Surveillance Device Detection With Countermeasures" and filed Jun. 29, 2009, now U.S. Pat. No. 8,340,252 and is a continuation-in-part of U.S. patent application Ser. No. 12/322,733, entitled "Safety Socket" and filed Feb. 6, 2009; the disclosures of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a system for monitoring electrical power. More specifically, the invention relates to an electrical socket monitoring and reporting system.

BACKGROUND OF THE INVENTION

Electrical receptacles, also known as outlets, wall plugs, etc., which in residential applications are commonly found mounted in an outlet box fixed within a wall and attached by terminals to an insulated powerline. By example, the typical powerline used for residential purposes has a line that has three wires, the first conducts the AC power wave, which is commonly known as the "hot", the second this a return line, commonly referred to as "neutral" and a solid copper conductor commonly referred to as "ground".

The typical receptacle has two parallel slots, and a third opening for the ground; behind each is a contact. Spades, also referred to as prongs, extending from a plug, conduct power by engaging the contacts. When the receptacle is connected to the line and the circuit is energized, the contacts are live. Safety, energy conservation and clean power (consistent power with low noise) are all concerns today with respect to electrical power. Monitoring power is the solution to all three concerns.

Measuring energy is routinely accomplished by use of power meters and has been enhanced to the benefit of the utility companies by the use of smart metering to measure total power consumption in real time. None of the concerns safety, energy conservation, or power Quality is addressed through smart metering. Energy monitoring systems in the current state-of-the-art make several troubling assumptions. First, the state-of-the-art assumes a site, whether it be residential, commercial or industrial, are wired correctly. Second, state-of-the-art metering systems assume the devices in the network are functioning correctly. And third, state-of-the-art metering systems fail to indicate how much energy is being consumed by a device or whether that device is functioning properly.

Electrical safety is a concern which is not addressed by state-of-the-art metering systems. A common safety concern is electrical shock resulting from insertion of an object into one of the receptacle slots. The art is replete with solutions to the threat of potential electrocution associated with a child inserting a conductive object in the receptacle.

There are multiple solutions in the art consisting of covers and inserts to prevent electrical shock. However these devices may become damaged and worn from the constant insertion and removal, which may also lead to neglecting their use altogether. In addition, small children may also pry off the covers to discover the mystery that lies beneath.

One such solution to this problem is the invention disclosed in U.S. Pat. No. 7,312,394, entitled "Protective device with tamper resistant shutters". The '394 patent discloses a receptacle cover assembly having a shutter. The shutter is movable to an open position by the insertion of at least one plug blade having a predetermined geometry Although the '394 patent offers a measure of protection, it has no power shut off safety feature, which would prove critical if an object other than a plug blade were able to deceive the device.

To prevent electrical shock in bathrooms, building codes require the use of ground fault interrupt "GFI" receptacles. In principle, these devices operate by measuring the current difference between the hot and neutral lines. If a threshold difference is reached a switch is opened and conduction to the contacts within the receptacle is terminated.

One such device is disclosed in U.S. Pat. No. 7,227,435 entitled "GFCI without bridge contacts and having means for automatically blocking a face opening of a protected receptacle when tripped". The '435 patent discloses an invention which prevents insertion of the prongs of a plug when the GFI circuit is tripped in the event of mis-wiring or a switch failure. When the device is tripped, an arm moves downward causing the contact to open and a blocking member is moved to a blocking position. However, a concern with this system is in the event of a failure, the contact will not open, nor will the blocking member be moved into the blocking position.

One solution to the failing GFI switch is found in the invention disclosed in U.S. Pat. No. 7,317,600 entitled "Circuit interrupting device with automatic end of life test". The '600 patent discloses a GFI circuit capable of simulating a ground fault to determine whether the device is working properly. An integrated circuit chip is connected to switch that interacts with the reset button. A user can determine whether the device has failed by engaging the reset button. However, the user still needs to manually test the device to verify that it is working. Furthermore, the device is normally closed, making the contacts "hot" and hazardous.

Another electrical safety concern is fire resulting from arc faults or appliances malfunctioning. None of the aforementioned solutions address the problem of fire detection or prevention. One source of fires is an arc fault. An arc fault may be a parallel fault, that is a discharge arcing between the hot line and neutral line, resulting from defects such as lack of insulation between the hot line and neutral line. A series fault is another type of discharge event resulting from defects such as a broken line, loose connection or other single wire failure. A ground arc results from loose grounding straps, shorts to ground and worn insulators of these types of arcs create sufficient heat to cause a fire. A fire can also be caused by a degrading device such as an electric motor overheating. Although many of these causes of fires could be prevented with proper maintenance the defects are either overlooked or not detected. The ability to measure temperature, detect an arc fault or detect a degrading or failing device would be beneficial.

Another concern today is energy conservation which relates to power consumption. Smart meters utilized by utility companies, although reporting in real time, only provide consumption information for an entire account, and not at the device level. A failing or overloaded device for example may consume more power than it should or more power than it historically has. An example of monitoring energy consumption at the device level is to monitor consumption at a receptacle. One advantage of this is the ability to measure the power being consumed by a failing device. It would be advantageous to provide a system for monitoring energy consumption at a receptacle.

Still another concern is the quality of power in the system. Poor power quality can be traced back to the electrical utility company or by interference from a device, in either case, these power disturbances resulting in poor power quality may cause device failure or damage to sensitive electrical devices.

Thus, it is desirable to provide a safety socket that can determine whether a plug has been engaged with the load side of the receptacle or if some other object had been placed into one of the slots, monitors and reports power consumption at the receptacle, detects arc faults and electrical problems as well as power disturbances. Additionally, it is also desirable to provide a receptacle that is normally open until a plug is engaged into the load side. Finally, it is also desirous to provide a receptacle that can communicate the device's state to external devices.

SUMMARY OF THE INVENTION

A system for monitoring an electrical device comprises at least one reporting device. The reporting device comprises a switch for connecting a power line to a load, where the switch has a control input. The reporting device has at least one sensor for producing a sensor signal indicative of a condition. The reporting device also has a transceiver for transmitting communications and receiving instructions. The reporting device has a control circuit in communication with the transceiver, the sensor and the switch, whereby the control circuit responds to the sensor signal or instructions by producing a command signal to the control input. The control circuit has a first mode of operation when the sensor signal is below a threshold where the switch is maintained in a conductive state, a second mode of operation when the sensor signal is above a threshold where the switch is rendered non-conductive, and a third mode of operation where instructions command the switch to be non-conductive. The system further includes a remote monitor which receives communications from the reporting device and transmits instructions to the reporting device.

The reporting device receives instructions from the monitor to transmit a reporting device status of the reporting device and the control circuit responds by producing a reporting device status and transmits a communication comprising the reporting device status of at least one reporting device.

The remote monitor may communicate with at least one reporting device wirelessly. The control circuit further produces data in response to a sensor signal. The communications from the reporting device may include data and sensor signals.

The sensor may measure current and the reporting device may further comprise a voltage sensor, where the voltage sensor is in communication with the control circuit.

The remote monitor may be in communication with a network to send and receive communications, the system further comprising a server operating within the network capable of receiving communications from the remote monitor. The server further comprises a sub-system for comparing communications from the monitor to predetermined thresholds.

The server further comprises a sub-system for creating a response signal in response to communications from the monitor. The response signal may notify third-party of a condition detected at least one of the reporting devices.

In one embodiment the monitor is in communication with a network to send and receive communications comprising power consumption. A server may be in communication with the network where the server is capable of receiving communications from the monitor. The server may further comprise a subsystem for comparing communications from the monitor to previously receive communications.

In another embodiment the server comprises a subsystem for creating report from communications received from the monitor. The system may further comprise a subsystem for creating a response signal in response to communications from the monitor. The system may generate a response signal indicative of power consumption at one of the reporting devices and communicate that response signal to the user.

The system may provide device status information that includes an identifier of at least one reporting device.

Further objects, features and advantages of the present invention will become apparent to those skilled in the art from analysis of the following written description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a prior art environmental illustration of an electrical receptacle shown connected to a common electrical power line and breaker box with a detail of the wires that comprise a power line;

FIG. **2** is a is a prior art environmental illustration of an electrical receptacle shown connected to the wires of a common electrical power line of FIG. **1**;

FIG. **3**A is a is an exemplary embodiment of a reporting device according to the principles of the present invention;

FIG. **3**B is a partially exploded view of the reporting device of FIG. **3**A, revealing a circuit board;

FIG. **4** is a sectional view of the reporting device of FIG. **3**B, further revealing protected hot and neutral bus bars;

FIG. **5** is a schematic illustration of an exemplary protection circuit according to the principles of the present invention, comprising a switch having a control input to render a switch conductive or non-conductive;

FIG. **6** is a schematic illustration of exemplary temperature measurement module for detecting temperature of each of a hot and neutral bus line according to the principles of the present invention;

FIG. **7** is a schematic illustration of exemplary power measurement module for sensing power and current for each of a hot and neutral line according to the principles of the present invention;

FIG. BA is a sectional view of the reporting device of FIG. **3**B, revealing an embodiment of a prong detector according to the principles of the present invention;

FIG. **8**B is a diagram of one embodiment of a prong detector according to the principles of the present invention;

FIG. **8**C is a schematic representation of a pair of prong detectors of FIG. **8**B, revealing the operative elements therein;

FIG. **8**D is a schematic representation of a pair of filters for filtering out ambient light from the detectors of FIG. **8**C;

FIG. **9** is a schematic illustration of a microcontroller employed in one embodiment of the present invention;

FIG. **10** is a schematic illustration of multiple reporting devices in communication with a monitoring device;

FIG. **11** is a schematic illustration of multiple monitors in communication with a server;

FIG. **12** is an exemplary data flow chart.

FIG. **13** is a line monitoring circuit for determining whether the line is in use according to the principles of the present invention;

FIG. **14** is a test generation circuit producing a test signal to be injected into a line and issuing test commands according to the principles of the present invention;

FIG. **15** is a test switch circuit for directing a test and a response signal to a desired line according to the principles of the present invention; and

FIG. **16** is a line interface circuit for breaking a line connection according to the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In a building that receives electrical power, whether commercial, industrial or residential, the electrical power is distributed into multiple circuits, commonly known as branch circuits, by a master control panel. The master control panel, also known as a breaker box, comprises a case containing circuit breakers for disconnecting branch circuits, including the main which disconnects all service to the branch circuits. Each branch circuit is protected by a circuit breaker. Protection for a branch circuit is governed by the current limit by each circuit breaker. For example, for a branch circuit that is protected by a 20 amp breaker, when 20 amps is exceeded the breaker automatically disconnects, interrupting power to the corresponding branch.

A circuit breaker only monitors one condition-electrical current. There are several other conditions that indicate the health of a branch circuit beyond current. Conditions such as voltage, frequency and temperature may also provide insight into the health of a branch circuit. A circuit breaker has a predefined current limit and remains in a conductive state until the current limit is exceeded. However, there are many other concerns with electrical power that are not detected by a circuit breaker. The state of a branch circuit, such as arcing, incorrect voltage, excessive current draw below the breaker threshold, high temperature, high power consumption, low appliance efficiency and feedback are examples of states of a branch circuit. The present invention will now be described with reference to the illustrations.

Referring now to FIG. **1**, a prior art environmental illustration of a branch circuit including an electrical receptacle **1**, which is shown connected to a common electrical power line **5** and breaker box **3** with a detail of the wires that comprise a power line **5**, a hot wire **2**, a neutral wire **4** and a ground wire **6**. Electrical power line **5** conducts electricity through the branch circuit of FIG. **1**.

Referring now also to FIG. **2**, a prior art environmental illustration of a residential 120 V electrical receptacle **1** is shown connected to a hot wire a neutral wire **4** and a ground wire **6**. The receptacle **1** comprises a neutral aperture **7**, a hot aperture **8** and a ground aperture **9**. The receptacle **1** typically receives prongs from a power cord of an electrical load (not shown). As used herein "load" shall refer to any electrical device connected to a branch circuit, including residential appliances such as a stove, refrigerator, clothing dryer or personal computer, commercial devices such as rooftop air-conditioning units and industrial devices such as conveyor systems, welding machines, or robots.

Referring now also to FIG. **3**A, an exemplary embodiment of intelligent switchable device **10** according to the principles of the present invention is shown in an embodiment for a residential application. It should be noted that although the exemplary embodiment is adapted to a residential 120 V receptacle, this is by no means limiting. Quite the contrary, as an example, the present invention may be embodied in a housing within a power cord, such as the transformer box of a laptop power cord. Furthermore, the device **10** may be employed in branch circuits of any voltage or current. For example, the present invention may be employed in 120 V, 230 V, 240 V, 400 V and 480 V circuits in frequencies of 50 or 60 Hz and in single or three phase circuits. It should also be understood that the present invention may be employed with various connectors, including the various NEMA configurations.

Referring still to FIG. **3**A, the device **10** resembles a receptacle **1** and fits within a typical wall box. The device **10** has a load side **11** and a line side **12**. A typical powerline **5** connects at the line side **12** of the device **10**. The typical residential powerline **5** has a conductor carrying the AC power wave, or hot wire **2**, the return line, also known as the neutral wire **4**, and a solid copper conductor that is tied to ground, referred to as the ground wire **6**. The device **10** is secured to the hot wire **2** at terminal **27**, the neutral wire at terminal **28** and the grounding wire **6** is secured at ground terminal (not shown) on a ground strap, such as the strap **16**.

The device **10** comprises a housing **15** supported by a strap **16**. Referring now also to FIG. **3**E, a partially exploded view of the reporting device of FIG. **3**A is shown revealing a circuit board. **20** within the housing **15**. On the Load side **11** of the reporting device **10** is a face **29** where sockets **14**A and **14**B are located, each of which having a neutral aperture **17**, hot aperture **18** and a ground aperture **19**. Sockets **14**A and **14**B are shown receiving plugs **13**A and **13**B, respectively. Plugs **13**A and **13**B have a plurality of prongs **25** extending therefrom. Prongs **26**, are also known as pins or spades, which couples the plugs **13**A and **13**B to sockets **14**A and **14**B.

Referring now also to FIG. **4**, a sectional view of the reporting device **10** of FIG. **3**B, further revealing a circuit board **20** coupled to protected hot bus bar **23** and protected neutral bus bar **24**. Protected hot bus bar **23** and protected neutral bus bar **24** receive the hot and neutral prongs **26** of plugs **13**A and **13**B. Protected hot bus bar **23** and protected neutral bus bar **24** are "protected" by a protection circuit that will be further illustrated in FIG.

Referring now also to FIG. **5**, a schematic illustration of an exemplary protection circuit **30** according to the principles of the present invention is shown. Unprotected hot bus bar **21** and unprotected neutral bus bar **22** receive power from the power line **5**. A surge protector **25**, which in the present embodiment is a gas discharge tube, is coupled between unprotected hot bus bar **21** and unprotected neutral bus bar **22**. A switch **33**, which in the preferred embodiment is a double pole double throw switch, is disposed between unprotected bus bars **21** and **22** and protected bus bars **23** and **24**. The switch **33** is triggered by a relay **32** which is commanded by the protection circuit **30**. In the preferred embodiment, relay **32** is comprised of latching relays K1 and K**2** to command the switch **33** to change poles, or flip the state from conductive to nonconductive or nonconductive to conductive, rather than to continually apply power to the relay **32**.

Protection circuit **30** comprises IC**12** which receives an input from OR gate **31**. The OR gate **31** receives signals GFCI_DET_**2** and TRIP_MAIN_**2** if either is true IC**12** will command relay **32** to open the switch **33**. A reset signal RST_MAIN_**2** will command relay **32** to close the switch **33**. The signals TRIP_MAIN_**2** and RST_MAIN_**2** are generated by a control circuit **90**, described in more detail below. TRIP_MAIN_**2** indicates a control circuit decision to open the switch **33** and RST_MAIN_**2** indicates a control circuit decision to close the switch **33**.

A GFCI detection circuit **35** includes IC**5** and receives signals from a GFCI neutral sensor **38** and GFCI hot sensor **39** to determine if a ground fault has occurred. In the preferred embodiment sensors **38** and **39** are hall effect sensors. Power for IC**5** is provided by the power taken from the unprotected hot bus bar **21** which passes through the resistor network **36** and protective diode **37**. When a ground fault is detected a

SCR_TRIG signal from IC5 is fed to NPN transistor Q1 which triggers the GFCI_DET_2 signal. Detection signal from detection circuit 3 is fed to an OR gate 31 and then to 1012 to trigger the relays 32. A GFCI test circuit 40 is provided consisting of a resistor network 41 and SCR T1 and diode D1.

In operation the switch 33 is commanded by control input 34 to render the switch 33 conductive or non conductive.

Referring now also to FIG. 6 is a schematic illustration of exemplary temperature measurement module for detecting temperature of each of a hot and neutral bus bars according to the principles of the present invention is shown.

Referring now also to FIG. 7, a schematic illustration of exemplary power measurement module for sensing power and current for each of a hot and neutral line according to the principles of the present invention is shown.

Referring now also to FIG. 8A a sectional view of the device 10 of FIG. 4 is shown, revealing a prong detector 70 according to the principles of the present invention. Protected hot bus bar 23 and protected neutral bus bar 24 are disposed within the device 10. Each of the protected hot bus bar 23 and protected neutral bus bar 24 are disposed adjacent to each of the apertures 17, 18. Specifically, the protected neutral bus bar 24 is disposed adjacent to the neutral aperture 17 and protected hot bus bar 23 is disposed adjacent to the hot aperture 18 to permit conduction with a user engageable contact, such as the prong 26 of a plug 13A, when inserted into one of the apertures 17, 18. For example, when the prongs 26 of plug 13A are inserted into apertures 17, 18, 19 the conductive material of the prongs 26 permit conduction with the hot and neutral contacts 23, 24 (the ground contact is not shown).

The prong detector 70 is disposed in the device 10 and includes of an emitter 71 and detectors 72, 73. Each of the detectors 72, 73 emit a first signal to indicate the absence an engageable contact in one of the apertures 17, 18 and a second signal, distinguishable from the first signal, to indicate the presence of an engageable contact in apertures 17, 18.

Referring now also to FIG. 8B, a diagram of one embodiment of a prong detector according to the principles of the present invention is shown, revealing the operative elements therein. In the preferred embodiment, the emitter 71 produces light and the detectors 72, 73 produces a signal indicative of the level of light detected. Partitions 24 are provided to minimize the interference of ambient light on the detectors 22, 23. The partitions 74 each have an aperture 75 disposed therein to permit light from the emitter 71 to reach the detectors 72, 73. Each of the prongs 26 when properly inserted will interfere with light from the emitter 71, causing a "no light" or "low light" signal from the detectors 72, 73. Therefore if both detector 72 and detector 73 indicate a low light signal, a plug is presumed to be coupled to device 10. As such when the emitter 71, detectors 72, 73 and partitions 74 with apertures 75 are positioned properly, the presence or absence of the user engageable contact such as prongs 26 may be detected.

Although residential applications have been referenced herein those skilled in the art will immediately recognize that the application of the presence invention may be employed beyond residential and specifically may also employed in commercial and/or industrial applications. Additionally, even though light emitting and detecting methods are specifically disclosed herein, it is intended to be within the scope of the present invention that other means of detecting the presence of plug blades be substituted for the light emitting and detecting methodologies disclosed herein.

Referring now to FIG. 8C, a schematic representation of a pair of prong detectors of FIG. BE, revealing the operative elements therein is shown. In the present embodiment, the emitter 71 is a light emitting diode, or "LED." For example, it maybe of the type such as a GaAs infrared, emitter. The detector 72 is an infrared phototransistor, which, as more light strikes the phototransistor, the higher the current flowing through the collector emitter leads causing a "high light" signal from the detectors 72, 73. The circuits in FIG. 8C act like a voltage divider. The variable current through the resistor causes a voltage drop.

As a precautionary measure, in the preferred embodiment, the LED is modulated at about 100 kHz to produce a target frequency and then provided to a filtering circuit. 80 as shown in FIG. 8D. In the environment such as a wall box environment the optical signal detection reliability required of an electrical socket due to dust and debris that would impair detection, of light, from the emitter 71 and the device 10 is intended to function without maintenance. The device 10 is capable of discriminating between electro-optical emitters 71 and variable ambient lighting conditions. Ambient optical power leaking to the detector 72, 73 from various sources such as lamps and sunlight, and changes in emitter optical power due to aging are obviated by the frequency modulation detection scheme of the present sub-system of the present invention. Practical light sources change optical emissivity due to a number of causes over time. The frequency based approach found herein allows for compensation for the changes in optical emissivity and discrimination of sources. Only light at the modulated frequency would signal the interrupter circuit of the present invention.

Referring now also to FIG. 8D, a schematic representation of a pair of filters for filtering out ambient light from the detectors of FIG. 8C is shown. The signal that leaves the branch of FIG. 8C as 5NS_TIN enters the bandpass filtering circuit 80. The bandpass filter assists in eliminating erroneous signals that could be generated from ambient light by filtering the incoming voltage and therefore only signals energized by the LED which is modulated at about 100 kHz may pass. The output signal of the filtering circuit 80 TIN_D is then provided to a microcontroller 90 described in FIG. 9 as IC3.

Referring now to FIG. 9, a schematic illustration of a microcontroller 90 employed in one embodiment of the device 10 of the present invention is shown. The microcontroller 90 is a programmable logic device, and as such, any suitable programmable device may be substituted for the microcontroller 90 employed in the present invention. In the preferred embodiment, microcontroller 90 has a microprocessor, volatile memory and non-volatile memory. Microcontroller 90, also identified as IC3, receives signals produced by the detectors 72, 73. The microcontroller 90 has instructions to produce a third signal indicative of the presence of two or more engageable contacts 26 in the device 10 and a fourth signal, distinguishable from the third signal, to indicate the presence of less than two engageable contacts 26 in the device 10. The microcontroller 90 transmits one of the third signal or fourth signal to interrupter circuit to cause a switch to open or close. Additionally, microcontroller 90 receives signals from a number of other sensors, including a thermal sensor, current sensor, and a voltage sensor. The output of microcontroller 90 is operatively coupled to number of communication devices located within the device 10, including warning lights and audible alarms.

Microcontroller 90 also communicates through other communication conduits, for example, microcontroller 90 is shown coupled to a serial port, identified as 109. Additionally microcontroller 90 may communicate through the powerline or wirelessly, for example the use of a transceiver 95. The ability to communicate externally provides the device 10 with the ability to transfer data about the state of the circuit for storage on location or off-site. This enables the device **10** to report faults in real-time or to demonstrate gradual deterioration of a condition, such as high current or heat, over time. Such information could be crucial in determining the cause of a fire, for example.

Microcontroller **90** is programmed to command the device **10** to not conduct electricity unless the microcontroller **90** determines that a plug **8** is engaged with device **10** and not merely some other object inserted into one of the apertures **13**, **14**. This is achieved by determining the presence of two of two blades **9** inserted into the apertures **13**, **14** by the detectors **22**, **23**. Accordingly, the normal state of reciprocal **10** is that no power is conducted to contacts **15**, **16** unless a plug **13**A is determined to be connected to the device **10**.

The output signals PH_A and PH_B from the microcontroller **90**, based on signals from detectors **22**, govern the conductive state of the device **10**. Referring now also to FIG. **5**A, a schematic illustration of an interrupter circuit **50** according to the principles of the present invention is shown. The interrupter circuit **50** has a line side, a load side and a switch. The line side is operatively coupled to a source of electrical power, for example a 14-2 wire. The load side is operatively coupled to the conductor contracts **15**, **16**. A switch is coupled between the line side and the load side to govern the flow of electrical power to the conductor contacts **15**, **16** based on the signals from the detectors **22**, **23**.

The interrupter circuit **50** governs the flow of electrical power to the conductor contacts **15**, **16** based on the signals received from the detectors **22**, **23**. The circuit **50** comprises a switch employing four silicon controlled rectifiers T**1**-T**4** to open or close the AC power wave. Each SCR is provided to conduct or not conduct a half wave coming into the device **10** through terminal **1** or **3**. Ideally only two SCRs should be necessary, however in the event of miss wiring the hot and neutral lines two SCRs are provided on the neutral line as a safety precaution. The signals from PH_A and PH_B are provided to the gate of the SCRs. When PH_A and PH_B provide voltage sufficient to conduct across the SCRs, the interrupter circuit **50** is conductive. Note that T**1** and T**2** are in parallel, but flipped. This is because the SCRs only work in one direction. A diode bridge B**2** is provided to rectify AC power to DC. Additionally, GFI protection is provided at TR**6** and TR**5**. FIG. **5**B is an alternate embodiment of the interrupter circuit of FIG. **5**A, further comprising a power transformer TR**3** in front of the bridge diode of the power supply.

Referring now also to FIG. **10**, is a schematic illustration of multiple devices **96**-**99** use an RF Mesh topology to communicate with a monitor **100**. Devices **96**-**99** use a 2.4 GHz wireless mesh network, which in the preferred embodiment is the ZigBee standard for communicating among the devices **96**-**99** and the devices **96**-**99** and a monitor **100**. As set forth above, the device **10** may take several forms, for example, power strips **98**, **99** and receptacles **96**, **97**.

In operation, the device **10** of the present invention is able to monitor multiple conditions, such as current, temperature, power, and change in VKN and conduct multiple tests. Once installed, the device **10** will have a unique identifier and then will conduct a baseline reading of the branch circuit that the device **10** governs. As set forth more fully below, the invention extracts phase shift information about a circuit from the reflection signal, characterizing and reporting a unitless but repeatable and predictable value, referred to herein as the Vasquez Kuttner Number ("VKN"). This technique becomes a signature of the circuit under test and forwards the information to the server **200** through a monitor **100**.

The device **10** can be used for monitoring the branch circuit by automated repeated testing in order to detect changes indicative of faults, wiretaps, or the presence of unauthorized equipment. Additionally, the history of the condition of a branch circuit may be recorded.

The device **10** can create and store a generated document with a reference number hereinafter called the Vasquez Kuttner Number (VKN,) a unique number that, once stored in the database **200**, becomes categorized as a representative signature to the configuration of the branch circuit under test and assigned to the device **10**.

The same test conditions may result in different VKNs for different devices **10**. The power conditioned apparatus measures the attenuation effects of branch circuits that is vulnerable to the physical layer, electrical characteristics, and equipment with frequency pulses, then calculates the measured electrical protected value and converts the wiring and hardware design of the telecommunications network into an alert readiness and resolve technique. It will report the out-of-service or degrading network systems.

The device **10** will create and display a reference number hereinafter called the Vasquez Number (VKN,) a unit less number that, once generated, becomes a representative signature of the configuration of the circuit under test. Since frequency pulses are attenuated by junctions, impedance, capacitance and other electrical/electronic devices in the circuit, each unique circuit configuration will attenuate one or more frequencies in a unique way. If ultimately plotted on a graph, the individual values that make up the VKN can be used to create a "fingerprint" of the circuit. Because two identical circuits would have the same measured values for all frequency pulses, identical circuits will cause the apparatus to generate the same VKN as well as the same "fingerprint" for both circuits.

FIG. **10** is a schematic illustration of multiple reporting devices in communication with a monitoring device.

FIG. **11** is a schematic illustration of multiple monitors in communication with a server.

FIG. **12** is an exemplary data flow chart.

Referring now to FIG. **13**, a branch circuit monitoring circuit **220** for determining whether the branch circuit is in use according to the principles of the present invention is shown. The branch circuit monitoring circuit **220** includes a plurality of arrays **221**, **222**, **223**, **224** for testing a branch circuit condition interconnected to the device **10**. Each of the arrays **221**-**224** are electrically isolated from the lines **5**, and each of the arrays **221**-**224** are preferably optoisolator array.

Once the branch circuit state is known, the device **10** can be commanded to execute one of several test types. The device **10** can determine if a branch circuit is energized and immediately abort a test in progress. Alternatively, if a test is scheduled, the test can be suspended until the branch circuit is available if the test type would interfere with usage. Furthermore, a test type can then be executed that does not interfere with the conversation and does not require the phone to be in a NOT-IN-USE state to execute the test.

Referring now to FIG. **14**, a test generation circuit **230** having a controller **231** is shown. The controller **231** has a CPU (not shown) and memory storage (not shown) adapted to receive signals and transmit instructions. The controller **231** receives the digital signal indicative of branch circuit state for each branch circuit from the A/D **225**, and, based on the state of each branch circuit, produces instructions to further evaluate the branch circuit, as discussed further below. The controller **231** produces a digital signal to command a digital to analog converter "DAC" **232** to produce an analog signal, identified as STIM_O, to be injected into the line **5**.

In the preferred embodiment, the instructions executed by the controller **231** include instructions to transmit a test signal to at least one user selectable branch circuit, compare a test signal response measured from at least one user selectable branch circuit to a baseline response, report a change in branch circuit state when the difference between a test signal response and a baseline signal response exceeds a threshold, and issue a countermeasure based upon countermeasure settings.

In the preferred embodiment, a power amplifier (not shown) provides additional drive capability to the test signal as generated by the test generation circuit **230**. The controller **231** is capable of commanding any desired wave form, including a square wave, sinusoidal, triangular, or the like. The controller **231** is programmable to output a user specified test signal, however, it is the intent of the present invention to provide a test signal having a frequency above 50 KHz. In the preferred embodiment, the test signal, STIM_O, is a single frequency sine wave having a frequency above 50 KHz.

As used herein, "reflection" is understood to mean the response monitored on the same branch circuit through which the test signal was transmitted.

The test generation circuit **230** forms part of a stimulus response module which is user-configured. A user may select a test with an option to select a test compatible with an IN-USE state (Type 3) since a Type 1 or Type 2 test would not generally be available. However, the system may be configured to break a call under certain conditions, as set forth in more detail below.

Controller **231** is programmed to issue test commands to carry out desired tests. In the preferred embodiment, STIM_O is a sine wave having a frequency above 50 KHz. The commands will include a direction to disconnect the branch circuit and to test the branch circuit. If the line monitoring circuit **220** delivers a NOT-IN-USE state, the controller **231** will issue the test command.

As shown in FIG. **15**, the test command is transmitted to a test switch circuit **240**, having a plurality of switches **241**, **242**, **243**, **244**, collectively referred to as a switch matrix, for sending and receiving test signal. The test switch circuit **240** directs a test signal input and output to a desired line based on the test commands received. A control bus and integrated circuit control the switches **241**-**244**. Each of the switches directs a test signal to and from the designated line based on the test commands. Switch **241** directs all signals for the tip wires leading to the CO **6** side (input side) of the line **5**. The STIM_O signal is directed out by switches **241**-**244**. Once STIM_O is injected into a line, the response signal STIM_I is monitored on the designated branch circuit by selection of one of the lines on one of the switches **241**-**244**. Accordingly, switches **241**-**244** direct the STIM_O signal out by, and select the line and wire to monitor, for either the reflection or transmission.

For example, a test on a branch circuit will direct the STIM_O signal. Switch **43** directs the response of the test signal found on the branch circuit and identifies the signal as STIM_I.

FIG. **16** is a line interface circuit for breaking a line connection according to the principles of the present invention.

The foregoing discussion discloses and describes the preferred structure and control system for the present invention. However, one skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that various changes, modifications and variations can be made therein without departing from the true spirit and fair scope of the invention as defined in the following claims.

The invention claimed is:

1. An intelligent switchable device for selectively conducting electricity, said device comprising:

a switch for connecting a power line to a load, said switch having a control input;

at least one sensor for producing a sensor signal indicative of a condition;

a transceiver for (i) transmitting data, including communications and (ii) receiving data, including instructions;

non-volatile memory adapted for storing a program;

a control circuit in communication with said transceiver, said sensor and said switch, said control circuit producing a command signal in response to (i) a sensor signal or (ii) instructions, said control circuit having a first mode of operation when the command signal is maintained in a conductive state, a second mode of operation when the sensor signal is above a threshold where said switch is rendered non-conductive, and a third mode of operation where the instructions command said switch to be non-conductive.

2. The device of claim **1**, further comprising a monitor for receiving communications from said at least one reporting device and transmitting instructions to at least one reporting device.

3. The device of claim **2**, wherein said device receives instructions from said monitor to transmit a reporting device status of said device and said control circuit responds by producing a reporting device status and transmits a communication comprising the device status of said at least one device.

4. The system of claim **1**, wherein said monitor communicates with said at least one reporting device wirelessly.

5. The system of claim **1**, wherein said control circuit further produces data in response to a sensor signal.

6. The system of claim **5**, wherein said communications from said reporting device include data and sensor signals.

7. The system of claim **1**, wherein said sensor measures current.

8. The system of claim **7**, wherein said at least one reporting device further comprises a voltage sensor, said voltage sensor being in communication with said control circuit.

9. The system of claim **6**, wherein said monitor is in communication with a network to send and receive communications from said monitor.

10. The system of claim **6**, further comprises a server capable of receiving communications from said monitor.

11. The system of claim **10**, wherein said server further comprises a sub-system for comparing communications from said monitor to predetermined thresholds.

12. The system of claim **10**, wherein said server further comprises a sub-system for creating a response signal in response to communications from said remote monitor.

13. The system of claim **12**, wherein said response signal notifies a third party of a condition detected at said at least one reporting device.

14. The system of claim **8**, wherein said monitor is in communication with a network to send and receive communications, said communications comprising power consumption, said system further comprising a server operating within the network capable of receiving communications from said remote monitor.

15. The system of claim **14**, wherein said server further comprises a sub-system for comparing communications from said monitor to previously received communications.

16. The system of claim **14**, wherein said server further comprises a sub-system for creating a report from communications received from said remote monitor.

17. The system of claim **16**, wherein said response signal notifies a user of power consumption at said at least one reporting device.

18. The system of claim **3**, wherein said at least one reporting device provides a device status information that includes an identifier of said at least one reporting device.

19. A system for monitoring an electrical device, said system comprising:

at least one reporting device, said device comprising (a) a switch for connecting a power line to a Load, said switch having a control input, (b) at least one sensor for producing a sensor signal indicative of a condition, (c) a transceiver for (i) transmitting communications and (ii) receiving instructions, (d) a control circuit in communication with said transceiver, said sensor and said switch, said control circuit responding to the sensor signal or instructions by producing a command signal to said control input, said control circuit having a first mode of operation when the sensor signal is below a threshold where said switch is maintained in a conductive state, a second mode of operation when the sensor signal is above a threshold where said switch is rendered non-conductive, and a third mode of operation where the instructions command said switch to be non-conductive; and

a monitor for receiving communications from said at least one reporting device and transmitting instructions to at least one reporting device.

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